



# **CORROSION ANALYSIS OF FUEL PUMP COMPONENTS CAUSED BY USE OF MIXED FUEL GASOLINE AND BIOETHANOL**

**Cipto and Daniel Parenden**

Mechanical Engineering Study Program, Faculty of Engineering,  
Universitas Musamus, Merauke, Indonesia

## **ABSTRACT**

*Stainless steel material is a material that has superior properties, namely good resistance to corrosion. This makes use of a very large and varied, one of the uses in the automotive field, stainless steel is used as a component of fuel pumps. Stainless steel can experience corrosion if all or part of the protective layer is damaged, damage occurs because the liquid or strong acid solution is delivered by HCl. Corrosion testing uses the immersion method, the immersion solution used is a solution of gasoline / premium fuel mixed with bioethanol fuel with a percentage of bioethanol 20%, 50%, 85% and 100% (pure bioethanol fuel without gasoline / premium fuel). The immersion test was carried out for 10 weeks at room temperature. The study aims (1) to know the form of corrosion and the causes of corrosion events, (2) identify corrosion products, (3) determine the corrosion resistance of materials based on corrosion rates, (4) determine the effect of percentage bioethanol on corrosion rates.*

**Keywords:** Stainless steel, Bioethanol, Corrosion.

**Cite this Article:** Cipto and Daniel Parenden, Corrosion Analysis of Fuel Pump Components Caused by Use of Mixed Fuel Gasoline and Bioethanol, International Journal of Mechanical Engineering and Technology, 10(1), 2019, pp. 362–369.  
<http://www.iaeme.com/ijmet/issues.asp?JType=IJMET&VType=10&IType=1>

## **1. INTRODUCTION**

Stainless Steel Material is a high alloy steel material. Stainless steel has the feature of being resistant to corrosion and high temperatures, which is why stainless steel is widely used. In the field of automotive stainless steel there are many and varied uses, including as a fuel pump component. corrosion resistance capability is obtained from the oxide layer, especially the highly stable chromium layer attached to the surface protects steel against corrosive environments

Stainless steel is an alloy steel containing the main elements namely, iron (Fe), chromium (Cr) minimum 10.5% and carbon (C) maximum 1.2%. The role of Cr is as a passive layer.

Although Cr is generally a less noble metal than iron, but Cr is an active alloy which is suitable in electrochemical reactions, Cr Alloy causes better corrosion resistance of steel. (Stainless Steel and Corrosion, 2011)

Stainless steel can experience corrosion if it is in an acidic or basic environmental condition, even if there is chloride ion in the acidic environment, corrosion will become aggressive. (Stainless Steel and Corrosion, 2011)

There are two types of fuel pumps in automotive vehicles, namely, a mechanical fuel pump that is driven by the vehicle's own engine and an electric fuel pump that is driven by electric current on the vehicle itself. This study uses components of an electric fuel pump made of stainless steel material. The fuel pump is designed according to the characteristics of the vehicle and the type of fuel. The fuel pump used is a fuel pump for gasoline / premium fueled vehicles.

Gasoline / premium fuel is obtained through the petroleum distillation process into the desired fractions. The boiling points of this compound include 40 ° C to 220 ° C which consists of carbon compounds C5 to C12. The chemical composition of gasoline consists of unsaturated hydrocarbons (olefins), saturated hydrocarbons (paraffins) and cyclic hydrocarbons or aromatic hydrocarbons (Permana, 2010).

This study was made to test the ability / corrosion resistance of gasoline / premium fuel pump components when gasoline / premium fuel is mixed with bioethanol. Bioethanol used as a mixture of gasoline / premium fuels in this study refers to the Government's plan to use bioethanol as a mixture of gasoline / premium fuel contained in the Minister of Energy and Mineral Resources Regulation No. 32 of 2008 concerning Provision, Utilization and Fuel Trading Nabati (Biofuel) As Another Fuel.

Bioethanol is a fuel (ethyl alcohol with the chemical formula  $C_2H_5OH$ ) that is produced from biofuels. Bioethanol is a colorless clean liquid, when used it does not cause environmental pollution, and when burned bioethanol produces carbonic acid gas (carbondioxide or  $CO_2$ ) and water. The applicable bioethanol standard (based on premium specifications) is referring to ASTM (American Standard Testing of Materials). In accordance with the Indonesian National Standard of Bioethanol Quality (SNI 7390-2008), bioethanol contains a maximum chloride ion of 30 mg / L.

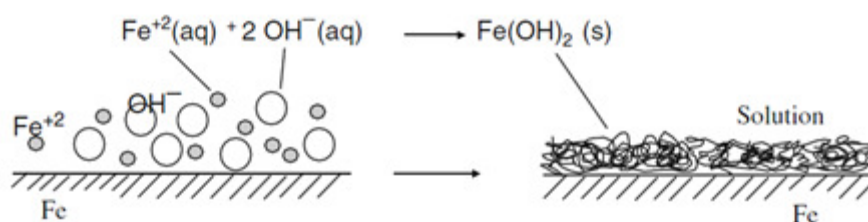
**Table 1.** Bioethanol test specifications according to SNI 7390; 2008 (Prihandana 2007)

No	Character	Unit. Min/Max	Specification
1	Ethanol Composition	%-v, min	94,0 (before denaturation) 99,5 (after denaturation)
2	Methanol Composition	mg/l, max	300
3	Water	%-v, max	1
4	Denaturation	%-v, min	2
5	Copper (Cu)	%-v, max	5
6	Density of 25°C	mg/kg, max	0,1
7	$CH_3COOH$ Acidity	g/mL	0,790
8	Appearance	mg/l, max	Clear and vivid, there is no sediment and dirt
9	Chloride ion level (Cl)	mg/l, max	30
10	Sulfur Composition (S)	mg/l, max	40
11	Gum Composition,	mg/100 mL.max	50
12	pH		6,5-9,0

Bioethanol is a fuel that has hygroscopic properties, this causes bioethanol to be corrosive. The use of bioethanol as an additive fuel in automotive vehicles has advantages, namely conventional fuel savings, and increased octane fuel numbers. The weakness of the corrosive properties of bioethanol can reduce the quality of the material, especially fuel system material, namely the fuel tank and fuel pump.

The risk is caused by tank leakage and fuel pump damage. So that it has the potential to threaten the safety of the driver / driver's life as the results of previous studies regarding uniform corrosion behavior and pitting in steel in ethanol solutions (RD. Kane 2004). In another study, the use of a 20% bioethanol mixture at premium caused corrosion of automotive components, the components most at risk of corrosion were copper and carbon steel material components (LM. Baena 2012). Department of Environment Australia and heritage, Stating 20% Bioethanol contains 1% of Water (Report to Environment Australia, 2003)

Corrosion occurs when there is a reaction of half the cell that releases electrons (anodic oxidation reaction) and the reaction of half the cell that receives the electron (reduction reaction in the cathodic). Both of these reactions will continue until there is a dynamic equilibrium where the number of electrons released is equal to the number of electrons received. For example, as seen in Fig. 1, where  $\text{Fe}^{2+}$  and hydroxyl react and form ferrous hydroxide corrosion products.



**Figure 1.** Corrosion products in the form of ferrous hydroxide(McCafferty.2009)

The metal corrosion reaction involves two half-cell reactions, namely the oxidation reaction at the anode and the reduction reaction at the cathode. The reaction of the cathode and anode that occurs in the corrosion process is as follows (Jonnes 1996).

Anode:



Cathode:

a. Hydrogen evolution (acid) :



b. Water reduction (neutral / alkaline):



c. Oxygen reduction (acid):



d. Oxygen reduction (neutral / alkaline):



e. Reduction of metal ions:



Based on the form of damage produced, the cause of corrosion, the environment in which corrosion occurs, and the type of material being attacked, the corrosion is divided into several types, including uniform corrosion (galvanic corrosion), crevice corrosion, corrosion pitting corrosion, intergranular corrosion, erosion corrosion, fretting, dealloying, hydrogen damage and environmentally induced corrosion (Jonnes 1996).

The corrosion process is affected by chloride. Chloride attacks the mild steel layer and stainless steel layer. Chloride ions are aggressive ions ( $\text{Cl}^-$ ) and sulfate ions ( $\text{SO}_4^{2-}$ ) and pH. The higher the concentration of chloride ion the corrosion rate tends to increase. (ASM Handbook Volume 13, 2003). Chloride ions react to destroy the passive layer on the surface of carbon steel. When chloride ions are dissolved in water, the chloride ion changes to hypochlorous acid ( $\text{HClO}$ ) and chloride acid ( $\text{HCl}$ ), which reacts to reduce pH (ASM Handbook Volume 13, 2003). Carbon steel which is directly exposed to the solution contains chloride ions, will experience corrosion and usually corrosion products in the form of uniform corrosion (ASM Handbook Volume 13, 2003).

## 2. MATERIALS

The material used in this study is a component of a gasoline fuel pump. (stainless steel material) indicated by figure 2.



**Figure 2.** Gasoline fuel pump



**Figure 2.** Components of a gasoline fuel pump, tested for corrosion resistance.

**Table 2.** Test Material Composition Data (Stainless Steel)

No	Parameter Result	Concentration	Unit	Methods
1	Aluminium (Al)	0,28	%	XRF (Omnian)
2	Silicon (Si)	0,42	%	
3	Chromium (Cr)	12,95	%	
4	Iron (Fe)	78,11	%	
5	Nickel (Ni)	4,28	%	
6	Copper (Cu)	0,19	%	
7	Zinc (Zn)	0,13	%	
8	Manganese (Mn)	0,84	%	
9	Cobalt (Co)	1,49	%	

### 3. METHODS

Corrosion test research uses an immersion test. The immersion test is carried out using 4 different types of solutions, namely the solution B80-E20 (Gasoline 80% -Bioethanol 20%), B50-E50 (Gasoline 50% -Bioethanol 50%), B15-E85 (Gasoline 15% -Bioethanol 85%) , B0-E100 (Gasoline 0% -Bioethanol 100%). The immersion test was carried out for 10 weeks at room temperature. To determine the morphology of corrosion, macro and micro photographs were carried out on the material before and after the immersion test.

Corrosion rate values obtained through the measurement of material weight loss (weight loss) are then calculated using the corrosion rate equation to determine the corrosion rate in Mpy units (Mils per year). The corrosion rate equation refers to the ASTM GI Assessment of Corrosion Damage as follows:

$$\text{Corrosion Rate} = \frac{K \times W}{A \times T \times D}$$

Where:

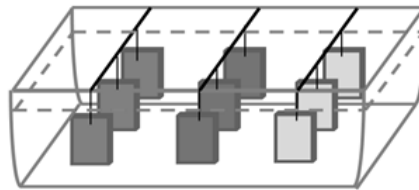
K :Constants

T :Time of exposure

A :Soaked surface area (cm<sup>2</sup>)

W :Losing weight (gram)

D : Density (  $\rho$  ) =  $\frac{m}{P \times L \times T}$ , gr/cm<sup>3</sup>

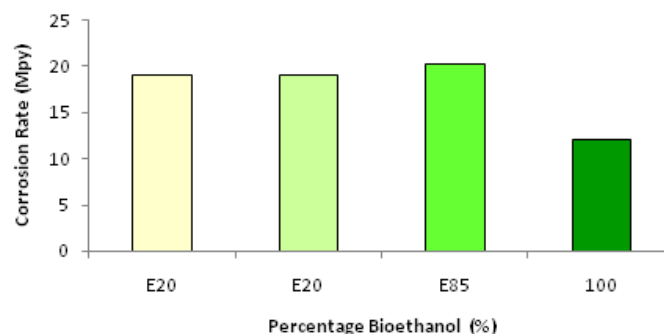


**Figure3.**Illustration of immersion

After calculating the corrosion rate, then the data is carried out statistical tests (linear regression) to find the relationship between two or more quantitative variables and test whether the correlation is significant or not.

In addition, other useful methods were provided (Latuheru and Sahupala, 2018; Razif et al., 2006; Waremra and Bahri, 2018).

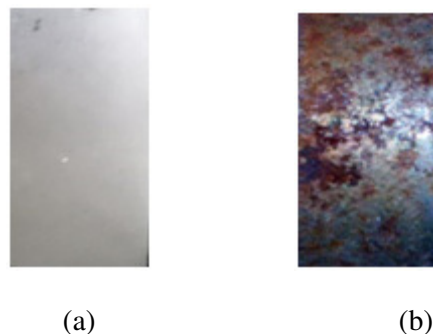
### 4. RESULTS AND DISCUSSION



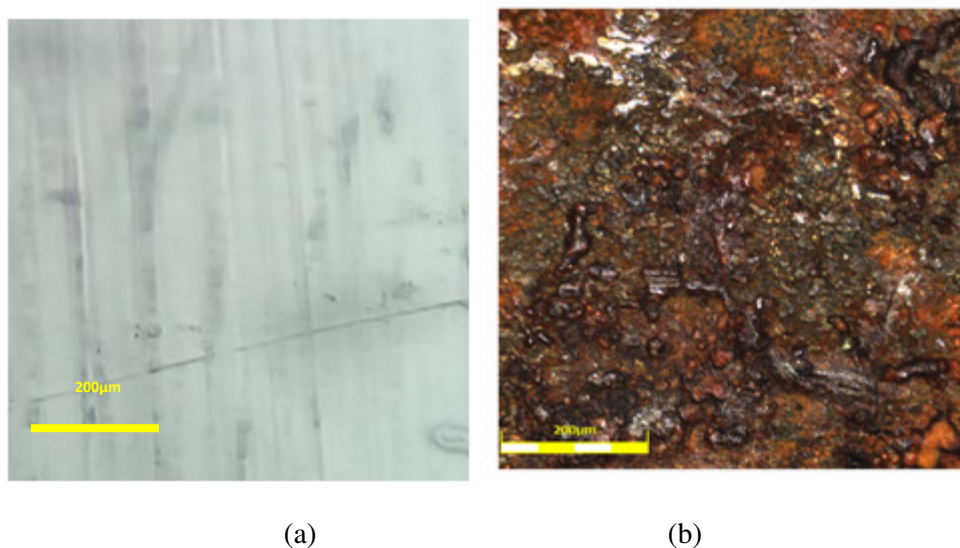
**Figure 4.**Graph of the ethanol percentage effect on the corrosion rate of stainlesssteel material

Figure 4 is a graph of the value of the corrosion rate based on the percentage of bioethanol content in the fuel mixture. The corrosion rate on E20 mixture is 19.00 Mpy, the corrosion rate of E50 mixture is 19.15 Mpy, the corrosion rate of E85 is 20.23 Mpy, and the corrosion rate of the mixture is mixed. E100 is 11.99 Mpy so that the highest order of corrosion rate is  $E85\% > E50\% > E20\% > E100\%$ . Corrosion of stainless steel material is caused by the presence of chloride ions in the solution which damage the passive layer, so that the damaged steel is passively corroded by  $H_2O$  which is the result of oxidation of hydrogen.

The highest corrosion rate value in figure 4 is found in E85 solution, the solution with higher bioethanol percentage, so that the content of chloride ion which is very reactive to stainless steel is higher, while other fuel mixture solutions with lower bioethanol content, lower chloride ion content, but different conditions on E100 (bioethanol 100%), the corrosion rate is lower. This can happen because in a 100% bioethanol solution, the hydroxyl content in bioethanol protects stainless steel.



**Figure 5.a.** Macro photo of stainless steel material before immersion and free from corrosion; **b.** Macro photo of stainless steel material after immersion in a mixture of fuel solutions and has been corroded.



**Figure 6.a.** Microstructure of stainless steel material before immersion and free of corrosion; **b.** Micro photo of stainless steel material after immersion and has been corroded.

The stainless steel material in figure 5a and 6a is material that has not been soaked and is free from corrosion, it appears the color of pure white material. While figures 5b and 6b are material that has been soaked and corroded so that it changes color, becomes black and brownish red. Corrosion formed in Fig. 5b and 6b is uniform corrosion.

### Steel reaction with bioethanol solution

Bioethanol is a pure compound fuel. Chemical reaction on bioethanol:



$\text{C}_2\text{H}_5\text{OH}$  bioethanol decomposes to form  $\text{C}_2\text{H}_5^+$  and Hydroxyl ( $\text{OH}^-$ ) compounds

Whereas in the steel anode reaction occurs:



Initial Fe is in equilibrium, then releases ions ( $2^-$ ) so that Fe is positively charged ( $2^+$ )

Reaction to steel and bioethanol:



From this reaction it is known that the compound  $\text{Fe}(\text{OH})_2$  is a corrosion product on the metal surface and compound  $2(\text{C}_2\text{H}_5)^+$  - formed in solution.

### Steel reaction with a gasoline solution mixed with bioethanol

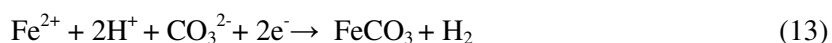
The hydroxyl produced in reaction 7 forms a further reaction as follows:



The  $\text{H}_2\text{O}$  formed reacts with the  $\text{CO}_2$  present at the gasoline



Carbonic acid ( $\text{H}_2\text{CO}_3$ ) formed then reacts with Fe



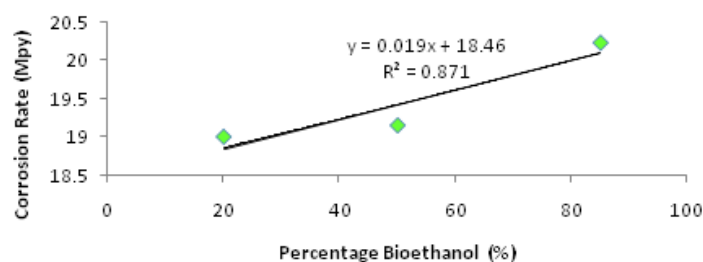
$\text{FeCO}_3$  formed from the reaction above is a corrosion product, the compound will form on the surface of the metal and  $\text{H}_2$  in solution.

Stainless steel material on fig 6 b and 7 b. It appears that the black corrosion product is  $\text{Fe}(\text{OH})_2$ , and the corrosion product that is brownish red is  $\text{FeCO}_3$ .

**Table 3.** Linear regression Test Data of bioethanol percentage in fuel mixture toward corrosion rate

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Observation
1	0.93333	0.871106	0.742211	0.340709	3

Based on table 3, it can be seen that the relationship between the percentage of bioethanol to the corrosion rate is very strong, namely the value of  $R = 0.93333$  and the percentage of bioethanol has an effect of 74.2% on the corrosion rate. The rest is influenced by factors outside.



**Figure7.** Regression Line



Based on the regression line in figure 7, it is known that the higher the bioethanol presentation in the fuel mixture the higher the corrosion rate of the stainless steel material.

## 5. CONCLUSION

- Corrosion of stainless steel material is caused by chloride ions contained in bioethanol, the corrosion formed is uniform corrosion.
- Corrosion products formed in the material are  $\text{FeCO}_3$  and  $\text{Fe}(\text{OH})_2$
- The corrosion rate at the 20% (E20) bioethanol percentage is 19.00 Mpy, at 50% bioethanol (E50) percentage is 19.15 Mpy, at 85% bioethanol (E85) percentage is 20.23Mpy, the corrosion rate continues increases according to the increase in the percentage of bioethanol in the fuel mixture, but at the percentage of bioethanol 100% (E100) the value of the corrosion rate is lower at 11.99 Mpy, this occurs because the hydroxyl contained in bioethanol protects the material
- Based on the linear regression test performed on bioethanol E20, E50, E85, increasing the percentage of bioethanol has a very strong effect on the corrosion rate.

## REFERENCES

- [1] ASM Handbook Volume 13 A, 2003. Corrosion: Fundamentals, Testing, and Protection
- [2] Jones, D. A. 1996. *Principles and Prevention of Corrosion*, Second Edition, Prentice Hall, Inc, United State of America
- [3] L.M. Baena, 2012. Aggressiveness of a 20% bioethanol–80% gasoline mixture on autoparts: I behavior of metallic materials and evaluation of their electrochemical properties
- [4] Latuheru, RD and Sahupala, P. 2018. Design of Methane Gas Capture Installation from Garbage Waste, *International Journal of Mechanical Engineering and Technology*, 9(10), pp. 279–287.
- [5] Permana, Agus. 2010. Pengaruh Penambahan Metanol Terhadap Angka Oktan pada Bensin Premium. Politeknik Negeri Sriwijaya. Palembang.
- [6] Prihandana, Rama, Kartika Noerwijan, dkk. 2007. Bioetanol Ubikayu; bahan Bakar Masa Depan. Agromedia Pustaka. Jakarta
- [7] R.D. Kane and J.G. Maldonado, 2004. Stress Corrosion Cracking In Fuel Ethanol: A Newly Recognized Phenomenon. Houston, Texas.
- [8] Razif, M., Budiarti, V.E., Mangkoedihardjo, S. 2006. Appropriate fermentation process for tapioca's wastewater in Indonesia. *Journal of Applied Sciences*, 6(13), 2846-2848.
- [9] Report to Environment Australia, 2003. A Testing Based Assessment to Determine Impacts of a 20% Ethanol Gasoline Fuel Blend on the Australian Passenger Vehicle Fleets.
- [10] Stainless Steel and Corrosion. 2011. First edition, first printing
- [11] Waremra, RS and Bahri, S. 2018. Identification of Light Spectrum, Bias Index and Wavelength in Hydrogen Lights and Helium Lights Using a Spectrometer, *International Journal of Mechanical Engineering and Technology* 9(10), pp. 72–76.